THE CHARLES STARK DRAPER LABORATORY
A DIVISION OF MASSACHUSETTS INSTITUTE OF TECHNOLOGY
68 ALBANY STREET
CAMBRIDGE, MASSACHUSETTS 02139

LUMINARY Memo #168

TO: Distribution
FROM: Robert Covelli
DATE: August 18, 1970
SUBJECT: "Erasable Memory Program" for a Guided RCS Burn.

In order to perform certain experiments during the APOLLO 12 and APOLLO 13 flights, it was planned to crash the empty LM ascent stage onto the lunar surface after rendezvous.

Both methods used the ullage from P42 to give the proper burn. In APOLLO 12, the flashing V99 N40 display was not answered, so that the ullage continued. When sufficient ΔV was accumulated, the ground controller keyed ENTER, which terminated ullage and went to the flashing V16 N85 display. The problem with this method was that the time delay between the ENTER keystroke and its transmittal to the spacecraft was not accurately known, and an overburn resulted causing the LM crash site to be in error.

In order to avoid this problem for APOLLO 13, the plan was to enable the P42 guidance equations during the ullage maneuver. This was done by clearing IDLEFLAG, after insuring that the ΔV monitor would not fail. When the P42 guidance equations determine that the burn is complete, they perform the engine shutdown routine, which, among other things, terminates ullage. This would produce an accurate cutoff with no overburn. The problem with this procedure, however, is that after termination of ullage, the V16 N40 display comes up over the V99 N40 display, causing a 31502 BAILOUT alarm. While this did not affect the performance of the burn, it was felt that a clean procedure should be developed for this type of burn.

All of the powered flight programs in the LGC utilize the same logic, with individual program logic controlled by a table specified by the erasable WHICH. The "WHICH tables" determine what displays are given, the amount of ullage, the guidance equation to be used, etc. Incorporation of the ACB L25 made it possible to use an erasable memory "WHICH table".

As a result, an "erasable memory" powered flight program can be easily uplinked to the LGC.

How to Write an Erasable Powered Flight Program

All that is required is an erasable "WHICH table", initialization of a few parameters, including WHICH, and a lead in routine that starts the new program. There are many precautions that must be observed when executing erasable programs. For example, it is obvious that the "WHICH table" must be in the same EBANK as WHICH. Also, the CALL instruction cannot be used in interpretive, but rather the basic routine E/CALL must be used. With this in mind, the following is developed for P99 - LM Deorbit.

1. The following parameters must be initialized:

DVTHRUSH	must be zeroed to prevent DVMON failure
WHICH	must be adress of "WHICH table"
F	set to 200 lb. or 400 lb., depending whether 2 jet or 4 jet ullage.
MDOT	initialize MDOT to APS value - (not used, but uplink easier if it is included)
TDECAY	must be zeroed - no decay for RCS jets.
VEX	initialize to RCS exhaust velocity.

2. The "WHICH table" should be as follows:

P99WHICH	+0	VN	0640
	+1	TCF	WANTAPS
	+5	TCF	P40SPOT
	+6	DEC	2990
	+7	ADRES	STEERING
	$+10_8$	BBCON	STEERING

```
+11₈    TCF     COMMON
+12₈    TCF     IGNITION
+13₈    TC      P99IGN  (erasable routine)
```

3. The lead-in to P99 should be as follows:

```
P99     TC      NEWMODEX
        DEC     99
        TC      INTPRET
        RTB
                E/CALL
        CADR    S40.1
        G0T0
                P40IN   +3
```

4. The routine P99IGN should be as follows:

```
P99IGN  TC      DOWNFLAG
        ADRES   IDLEFLAG
        TC      TASKOVER
```

5. The following assumptions are made:

   The LM is the ascent stage only.
   There will be no more IMU alignments. Because of these assumptions, the erasable programs and "WHICH table" can overlay the AOTMARK and landing radar pad loads in EBANK7.

6. The resulting "program" is as follows (all addresses are for LUMINARY 177) :

NAME	ECADR	OCTAL	SYMBOLIC	
P99WHICH	3404	01450	VN	0640
	3405	12324	TCF	WANTAPS
P99IGN	3406	05527	TC	DOWNFLAG
	3407	00161	ADRES	IDLEFLAG
	3410	05272	TC	TASKOVER
	3411	12150	TCF	P40SPOT
	3412	05656	DEC	2990
	3413	03667	ADRES	STEERING
	3414	74066	BBCON	STEERING
	3415	12404	TCF	COMMON
	3416	12433	TCF	IGNITION
	3417	01406	TC	P99IGN
P99	3420	05322	TC	NEWMODEX
	3421	00143	DEC	99
	3422	06042	TC	INTPRET
	3423	77634	RTB	
	3424	10607		E/CALL
	3425	56246	CADR	S40.1
	3426	77650	GOTO	
	3427	75202		P40IN +3

NAME	ECADR	OCTAL	SYMBOLIC		
F	3734	00026	2DEC	0.17792	B-7
	3735	30605	(400 lb)		
MDOT	3736	00151	2DEC	0.05135	B-3
	3737	05214	(APS	MDOT)	
TDECAY	3740	00000	2DEC	0	
	3741	00000			
VEX	3742	15400	2DEC	27 B-6	
	3743	00000	(27.00	M/CS)	
WHICH	3455	01404	ADRES	P99WHICH	
DVTHRUSH	1250	00000	OCT	0	
DVCNTR	3515	00004	DEC	4	
DSPTEM1	1044	13001	OCT	13001	
	1045	01420	ADRES	P99	
	1046	12067	BBCON	P99	

Description of P99

Prior to executing P99, the following must be done:

1. P30 or other targeting program must be done.
2. If desired, a V49 maneuver can be done.
3. PGNCS control, AUTO "mode selected".
4. APS Engine Arm must be off because the engine on bit is set.
5. P99 coding uplinked via the three P27 loads given in appendix.

To begin P99, key in V30E. (Noun 26 is loaded by the V72 uplink.) After the V30, the sequence is:

P99 in MODE light.	
Flashing V50 N18 -	V33E for trim
	ENTER for no trim
V06 N40 R1 counting down	
At TIG, ullage begins	
At cutoff, ullage stops	
Flashing V16 N40	V33E
Flashing V16 N85	V33E
Flashing V37	00E to P00.

It should be noted that P99 is a general program for guiding an RCS burn, and does not have to be used for LM deorbit only. Further testing is in progress to determine whether it can be used for the TPI burn in the short rendezvous planned for APOLLO 14. Also, if 99 is not desired as a major mode number, the contents of cell 3421 can be modified to whatever the user desires.

Two additional notes should be brought to mind. In order for the P00 integration routine to be terminated during P99, the P00H flag must be reset. The simplest way of doing this is to key a V96E. Also, N26 should be checked just prior to keying V30E to insure the locations haven't been overwritten by, e.g., any priority displays. To check these numbers, key V5N26E; R1 = 13001, R2 = 01420, R3 = 12067.

The astronaut cards for a digital simulation are attached.

APPENDIX

P99 uplink

Load 1	Load 2	Load 3
V71E	V71E	V72E
24E	12E	21E
3404E	3734E	3426E
1450 E	26E	77650E
12324E	30605E	3427E
5527E	151 E	75202E
161E	5214E	3455E
5272E	0E	1404E
12150 E	0E	1250E
5656E	15400E	0E
3667E	0E	3515E
74066E	V33E	4E
12404 E		1044E
12433E		13001 E
1406E		1045E
5322E		1420E
143E		1046E
6042E		12067E
77634E		V33E
10607 E		
56246 E		
V33E		

BACKGROUND = 00000

CARDS READ BY ASTRONALT INPUT-PROG 5 :

```
A       WAIT 2 V 48 E
A       IF V 01 N 46 THEN WAIT 1 V 21 E 12102 E WAIT 1 PROCEED
A       IF V 06 N 47 THEN WAIT 1 V 21 E +6250  E WAIT 1 PROCEED
A       W 20 V 37 E 30 E
A       IF V 06 N 33 THEN V 25 E +00108 E +00059 E +04700 E
A       IF V 06 N 33 THEN WAIT 1 PROCEED
A       IF V 06 N 81 THEN WAIT 1 V 25 E +00900 E + E + E
A       IF V 06 N 81 THEN WAIT 1 PROCEED
A       IF V 06 N 42 THEN WAIT 1 PROCEED
A       IF V 16 N 45 THEN WAIT 1 PROCEED
A       IF V 37 THEN WAIT 1 00 E
A       VERIFY EVERY 10 WITHIN 1000 M=00 THEN WAIT 2
A       V 96 E
A        GUIDEMODE PRIMARY SCSMODE AUTO
A       ASENGARM OFF
A       UPTEL FOLLOWS
A       V 71 E
A          24 E
A        3404 E
A        1450 E
A       12324 E
A        5527 E
A         161 E
A        5272 E
A       12150 E
A        5656 E
A        3667 E
A       74066 E
A       12404 E
A       12433 E
A        1436 E
A        5322 E
A         143 E
A        6042 E
A       77634 E
A       10607 E
A       56246 E
A       V 33 E
A       VERIFY EVERY 10 WITHIN 1000 M=00 THEN WAIT 2
A       ER
A       V 71 E
A          12 E
A        3734 E
A          26 E
A       30605 E
A         151 E
A        5214 E
A           0 E
A           0 E
A       15400 E
A           0 E
A       V 33 E
A       VERIFY EVERY 10 WITHIN 1000 M=00 THEN WAIT 2
```

```
A       ER
A       V 72 E
A         21 E
A       3426 E
A      77650 E
A       3427 E
A      75202 E
A       3455 E
A       1404 E
A       1250 E
A          0 E
A       3515 E
A          4 E
A       1044 E
A      13001 E
A       1045 E
A       1420 E
A       1046 E
A      12067 E
A       V 33 E
A       VERIFY EVERY 10 WITHIN 1000 M=00 THEN WAIT 2
A       ER
A       V 62 E
A       V 30 E
A       IF V 50 N 18 THEN WAIT 2 V 33 E WAIT 5
A       IF V 50 N 18 THEN WAIT 2 ENTER
A       T=392435.00 W 5
A       IF V 16 N 40 THEN W 2 V 33 E
A       IF V 16 N 85 THEN WAIT 2 V 82 E
A       IF V 16 N 44 THEN WAIT 2 V 33 E
A       IF V 16 N 85 THEN WAIT 2 V 33 E
A       IF V 37 THEN WAIT 2 00 E
A       V 82 E W 5 N 32 E W 5 KR V 33 E
A       WAIT 2 V 69 E

      END OF ASTRONAUT INPUT CARDS.


      ASTRONAUT READS 10 WORDS OF ASTRONAUT CARD INFORMATION
 8.88888888799  03   8.80000000000  09   5.00000000000  00   7.77777777699
 2.00000001600  09   3.00000004000  09   7.77777777699  03   8.88888888799

START SIMULATION.
```